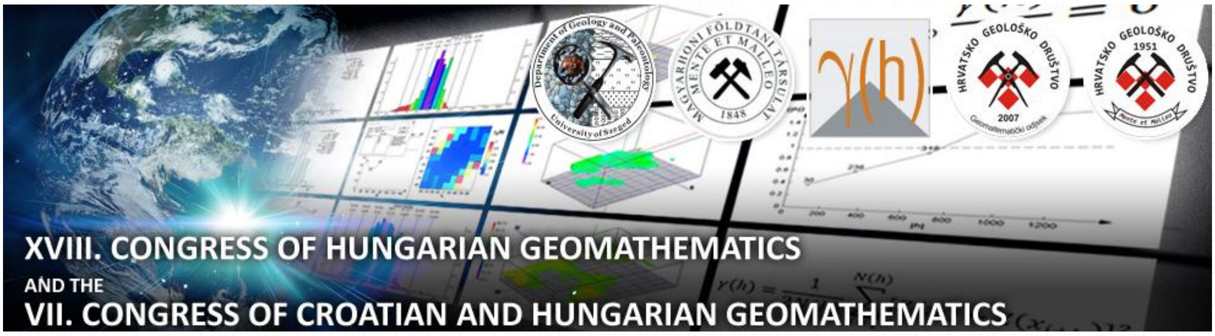

"The geomathematical models: the mirrors of geological reality or science fictions?"

Abstract & Program Book

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IMPRESSUM

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NOTE

The content of proceedings has not been passed English proof reading by native speaker, and that is why solely the authors are responsible for the quality of language usage.

PROGRAM

Thursday (21th May)

10:30-11:00 - OPENING CEREMONY

Janina **HORVÁTH** chairman, János **GEIGER** co-chairman, Marko **CVETKOVIĆ** co-chairman,

You are kindly requested to arrive in time

11:00-12:15 – 1st SECTION

Chairman: Marko CVETKOVIĆ

11:00 – 11:25	István **NEMES**
Combined Capillary Curves	
11:25 – 11:50	János **GEIGER**
Some applications of Markov-type sequential Gaussian co-simulations	
11:50 – 12:15	Kálmán **BENEDEK**
DFN Modelling: recent trends, capabilities, applications	
12:15 – 12:40	László **GYŐRY**
iCore – a unique approach to packing generation	
12:40 – 13:00	Janina **Horváth**
Identification of facies using Unsupervised Neural Network	

13:00 – 14:30 - Lunch break (Finger lunch in the lounge)

14:30- 2nd SECTION

Chairman: János GEIGER

14:30 – 14:55	Bruno **SAFTIĆ**, Iva TOMLJENOVIĆ, D. Arandia-KREŠIĆ, M. RISEK
Porosity distribution models for numerical estimates of the regional CO_2 storage potential in clastic sediments	
14:55 – 15:20	Marija **PODBOJEC**
Preliminary estimate of CO_2 storage capacity by geomodelling in Upper Miocene sandstones in the western part of Sava depression	
15:20 – 15:45	Marko **CVETKOVIĆ** & Josipa VELIĆ
Biogenic reactions and methane expulsion modelling from source rocks of Ravneš Member, Sava Depression	

15:45 – 16:10 - Coffee break

16:10 – 17:35	Angelika **SÓLA**
Facies study to enhance ultimate oil recovery: A case history from Algyő field, SE – Hungary	
17:35 – 18:00	János **BLAHÓ**
Facies modelling in the focus of reservoir modelling	
18:00 – 18:10	Levente **KISS (e-poster presentation)**
3D modelling of a hydrocarbon reservoir formed in a delta slope	

19:00 - Dinner (Varga Csárda)

Friday (22st May)

9:00-10:15 – 3rd Section

Chairman: Omar SLIMAN

9:00 – 9:25	Tomislav **BAKETARIC**
Subsurface modelling of the Neogene-Quaternary sediments based on digitalization of handmade regional geological maps	
9:25 – 9:50	Marcell **LUX**
Evaluation and Optimization of Multi-Lateral Wells Using MODFLOW- Unstructured Grid Code	
9:50 – 10:15	Mátyás **SANOCKI**
Importance of proper layering of 3D grids; how bedding parallel layering can enchance solve long-lasting stratigraphical and structural geological problems - a case study of facies modeling from the Tóalmas region, Hungary	
10:15 – 10:40	Zsuzsa **BRINZANEK**, Sándor TÓTH
Reservoir geology re-evaluation – case study of gas field of Pannonian age	

10:40 – 11:00 - Coffee break

14:30-16:00 - 4th Section

Chairman: Janina HORVÁTH

11:00 11:25	Andrea **WÁGENHOFFER**
Modeling geological structures with Training Image for Multiple-Point approach: from Theory to Practice	
11:25 – 11:50	Petra **SLAVINIĆ**
Subsurface volume calculation – a comparison between mathematical integration and cell-based models	
11:50 – 12:15	Noémi **JAKAB**
Uncertainty assessment based on static connectivity metrics	

12:30 – 14:30 - Lunch break Lunch break (Finger lunch in the lounge)

14:30 - 14:55	Viktor **VOLFORD**
Application of 3D seismic data to constrain the reservoir models	
15:20 – 15:45	Omar **SLIMAN**
Uncertainty delineation from the petrophysical modelling of Lower Nubian Reservoir	
15:45 – 16:00	László **ZILAHI-SEBESS** and Erika BODA
Recommended principles of the qualifications of geothermal plays	

16:00 – 16:20 - Coffee break

16:20- 5th Section

***Chairman*: István HATVANI**

16:20 – 16:45	Gábor **SZATMÁRI**
Using a sequential stochastic simulation approach based on regression kriging to generate functional soil maps	
16:45 – 17:10	Dániel **TOPÁL,** István Gábor HATVANI, István MATYASOVSZKY, Zoltán KERN
Break-point detection algorithms tested on artificial time series	
17:10 – 17:35	Sándor **GULYÁS,** Csilla BALOGH, Antónia MARCSIK, Pál SÜMEGI, Dávid KÓKAI
Geometric morphometric analysis of artificially distorted skulls from an Avar Age site near Makó, SE Hungary	
17:35 – 18:00	Petra **BODOR ,** József KOVÁCS, Anita ERŐSS, Judit MÁDL-SZŐNYI
Time series data analysis of parameters of lukewarm springs from the Rózsadomb area, Hungary	

18:30 - Dinner in the 'Puszta'

The 'Tuk-Tuk' departs at 18:30 from the square next to congress center. If you late you will walk…

From 22:00 (p.m.) shuttle bus is available from the site to 'Congress center'

Saturday (23st May)

9:00 – 9:25	Szabolcs **BORKA**
Analysis of deep-water clastic depositional systems' lithofacies based on their genetic by application of Markov chains and entropy tests	
9:25 – 9:50	Viktória **PATAKI**
3D modelling of a clastic turbiditic system and its uncertainty assessment: a case study from the Pannonian Basin, Hungary	

9:50 – 10:15 - Coffee break

10:15-11:30 - Workshop

Scope: "Geological models supported by geomathematics: the mirrors of geological reality or science fictions?"

First rule of the workshop: „Keep it in practice!"

- What is a model?
- Is modelling really necessary? Why?
- What are the goals of building models?
- What types of approaches are used for modelling in the industry?
- What are the most important input data?
- Common gaps and controversies in input data, challenges during setting up a geological model
- Processes and methods to overcome these difficulties
- How to handle uncertainties? How to differentiate and mitigate stochastic and conceptual uncertainty?
- Feedback on the models

***Moderators*:** István **NEMES,** Mátyás **SANOCKI**

Reservoir Geologists at MOL Group

11:30 – 12:00 – Closing ceremony

ABSTRACTS

***Baketarić*, Tomislav**: *Subsurface modelling of the Neogene-Quaternary sediments based on digitalization of handmade regional geological maps*

Benedek, Kálmán: *DFN Modelling: recent trends, capabilities, applications*

***Blahó*, János**: *Facies modelling in the focus of reservoir modelling*

***Bodor,* Petra et al:** *Time series data analysis of parameters of lukewarm springs from the Rózsadomb area, Hungary*

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***Brinzanek*, Zsuzsa & *Tóth, Sándor* :** *Reservoir geology re-evaluation – case study of gas field of Pannonian age*

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***Geiger*, János:** *Some applications of Markov-type sequential Gaussian co-simulations*

***Győry*, László:** *iCore – a unique approach to packing generation*

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Horváth,* Janina: Identification of facies using Unsupervised Neural Network*

***Jakab*, Noémi:** *Uncertainty assessment based on static connectivity metrics*

***Kiss*, Levente:** *3D modelling of a hydrocarbon reservoir formed in a delta slope*

***Lux*, Marcell:** *Evaluation and Optimization of Multi-Lateral Wells Using MODFLOW- Unstructured Grid Code*

***Nemes*, István:** *Combined Capillary Curves*

***Pataki*, Viktória:** *3D modelling of a clastic turbiditic system and its uncertainty assessment: a case study from the Pannonian Basin, Hungary*

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***Sóla*, Angelika:** *Facies study to enhance ultimate oil recovery: A case history from Algyő field, SE – Hungary*

***Topál*, Dániel et al:** *Break-point detection algorithms tested on artificial time series*

***Volford*, Viktor:** *Application of 3D seismic data to constrain the reservoir models*

***Wágenhoffer*, Andrea:** *Modeling geological structures with Training Image for Multiple-Point approach: from Theory to Practice*

***Zilahi-Sebess,* László & *Boda,* Erika:** *Recommended principles of the qualifications of geothermal plays*

Application of 3D seismic data to constrain the reservoir models

Viktor Volford
University of Szeged, Department of Geology and Palaeontology
viktor.volford2@gmail.com

Abstract
Well data provides frequently used dataset for building geological probabilistic models in order to characterize the target reservoirs but the relevance of the seismic surveys in the exploration and development of oil and gas fields can be perceptible in the last decades.
Exploration is enhanced by spatial predictions of the corresponding rock-types with different petrophysical properties in order to have ability to designate the promising reservoirs. Well logs provide high resolution information about rock and fluid properties in vertical section, but their utility is limited in lateral extent. Although their importance is inevitable for determining the lithology types based upon direct measurements around the wellbore. In contrary, seismic data have good spatial coverage which represents different measurement scale but can contribute the proper correlation between wells. Due to this fact a lot of researches have focused on the integration of the seismic and well data to reduce the uncertainty which associated with geological models coming from the sparse information from the wells at the development stage. The main idea is to use the information about the spatial variation of a well sampled variable originated from 3D seismic to help to interpolate a sparsely sampled variable derived from conventional well logs. The preconditions rely on a statistical relationship between seismic and internal properties or lithofacies to characterize the local distributions of these properties at any location of the reservoir by using cosimulation algorithm. The spatial continuity pattern of the combined primary and secondary variable can be modelled by cross-variograms. In this way the distribution of the sedimentary facies according to their petrophysical properties could be mapped with lower uncertainty and greater geological realism which are relevant in the sense of reducing the risk which is the unavoidable part of the exploration.

Key words: 3D seismic, co-simulation, correlation, reservoir modelling, uncertainty

1. INTRODUCTION THE RESERVOIR MODELLING

This theoretical study covered the essential model principles which related to geological and statistical concepts and methods to construct estimation maps and simulated models in the case of bivariate data integration. Reservoir models formed to reproduce all locally available data which have individual scale and accuracy. This various types of local information derived from direct and indirect measurements. With direct measurements the subsurface directly analysed with core samples, provide local information of the reservoir properties of interest with limited areal extent. Indirect measurements such as well logs and seismic attributes where the response of the rock is measured and then transformed into the inferred rock properties. Well logs are the high resolution indicators of facies and fluids conversely, seismic give information of the large-scale reservoir geometry and if the resolution is sufficient refers to their architecture and even the internal properties. Utilization of this different scale measurement away from the sampled location one of the greatest challenge in geostatistical reservoir modelling because requires a description about the pattern of spatial correlation between the variables. This goal of this study is the comparison between different approaches with their advantages and disadvantages, in order to give better estimation about the distribution of the lithofacies and petrophysical properties.

The process contains several main points: (1) lithofacies classification using Artificial Neural Network (ANN) (2) alternatives for data integration to create geostatistical model of facies considering to seismic data as a secondary variable (3) model the porosity distribution within each facies with Cokriging

2. MULTIVARIATE MAPPING

Various geostatistical methods were developed with their own assumptions, limitations and strength for the secondary data integration. The hardest task is the discretization of the relation between the soft and hard variables in the consequence of the different volume support and sensitivity to the petrophysical changes. Many geostatistical tools are account for the spatial correlation between them. For prediction the main technique is cokriging or cosimulation which can be applied in a multivariate Gaussian and indicator framework. A concern with all these techniques is the efficiency to measure the spatial correlation with cross-variograms where the model fitting is subjective, difficult in practice and requires large number of data. (Deutsch et all. 2014)

The complexity is rising if the variables are categorical. In many cases the predefined lithotypes have distinct character in well logs but their seismic response overlap or have great variability within the same facies as the result of their similar acoustic properties and even the correlation is non-linear. Consequently the statistical relationship could not be described or at least not advisable only with a simple correlation coefficient. This is the main cause why this study is supposed to present some probabilistic relation based methods and their utilization opportunity in lithofacies prediction.

3. ANN AND THEIR SIGNIFICANCE OF THE LITHOFACIES PREDICTION

Neural Network based clustering prefers because it offers the best result for the lithology determination from different type of well logs. The method is planned to identify the genetically homogenous subset from the multidimensional space using different weights for the inputs. For the resulting cluster centres more additional samples can be match. (Horváth, 2014) The aim to create such lithology logs which can be distinguish via seismic attributes. For that reason the input data focuses on that well logs, which implies the mechanical and acoustic properties. There are: sonic, density, AI, Vp/Vs.

4. METHODS FOR THE PROBABILISTIC LITHOFACIES EXTENSION

4.1 Seismic data in SIS

Because of the aforementioned behaviour of the facieses there are simplifying assumptions such as collocated co-simulation both in Bayesian and Gaussian form to consider only a collocated secondary variable. Indicator based approach will be discussed in details in this part of the study. The advantages of the SIS in facies modelling are the following: (1) simplified data integration because of the common probability coding (2) capability to capture the different continuity of extreme values published by Goovaerts (1994). The main idea of SIS is to determine the conditional probability of *F* mutually exclusive facies category *xf*, *f*= 1,….*F* at any location: 1 if present and 0, otherwise. The heart of the indicator simulation is the horizontal variogram calculation which is poorly defined from well data alone. A possible solution involves of using seismic data to support the 3-D variogram models. Co-simulation does not require explicit seismic to facies calibration through the cross covariance because of the ambiguity that is why the calibrated probability are preferred. (Deutsch et all. 2014). This procedure consists of two steps: (1) subdivision the range of the particular attributes variability into series of classes (2) determining the probability of each facies for each seismic class which is,

$$p(f|ai_j), \qquad f=1,\ldots\ldots,F, \quad j=1,\ldots.,N_{ai}$$

where $p(f|a_{ij})$ is the probability of facies type f for the j^{th} seismic class a_i.

The **Figure 1**. shows the calculated facies probability functions.

The calibration needs to be representative for the appropriate prior probability calculation. On behalf of that cause the sampling rate of the seismic data must be fit to the true vertical resolution to retrieve as most information as possible. Seismic data carries additional information only when those calibration probabilities depart from the global probabilities of each facies type. For describing the spatial correlation structure a set of *C* indicator variograms must be defined. The sparse well data provide the vertical indicator variograms, $\gamma_f(h)$ which are standardized to sill by the corresponding variance p_f $(1\text{-}p_f)$. If the seismic is highly correlated to the facies proportions an important assumption is that the seismic proportions provides a reasonable approximation to the horizontal indicator, *i,* range that is why we calculate the horizontal variogram from the corresponding seismic proportions $p(f|a_{ij})$. It is also need to be standardized to the sill. In the final step the vertical and horizontal variograms are fit to with the shape of the vertical indicator variogram, only the range and any zonal anisotropy is taken from the seismic proportion variograms. (Deutsch et all. 2014)

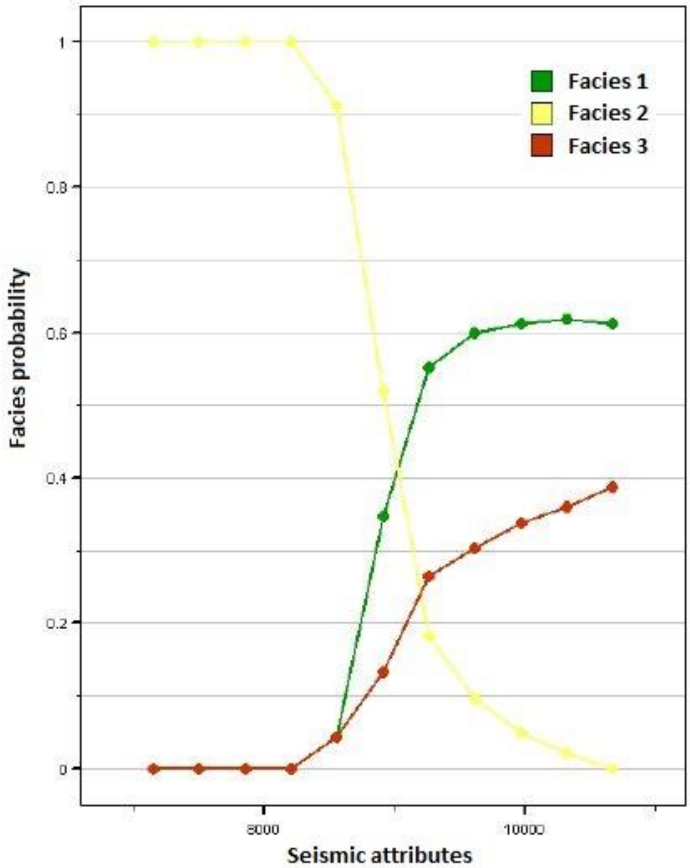

Figure 1: *Facies probability for the corresponding seismic classes (Modified after Roxar RMS User Guide, 2013)*

4.2 The Bayesian updating approach

One of the simplest forms of cokriging is the Bayesian Updating Approach. SIS gives the probability of each facies from hard data *i*, alone, and Bayesian updating modify that probability as follows:

$$i^{**}(u;f) = i^{*}(u;f) \cdot \frac{p(f|ai(u))}{p_f} \cdot C \qquad f = 1,\ldots,F$$

where $i^{**}(u;f)$, $f = 1,\ldots, F$ are the updated probability for simulation, $p(f|a_i(u)$ are the seismic driven probability of facies f at location u. p_f is the overall proportions of facies F and K a normalization constant to ensure that the sum of the probabilities is 0. $p(f|a_i(u))/p_f$ inspired to increase or decrease the probability depending on the difference among the calibrated facies proportions and the global proportions. No updates required when $p(f|a_i(u))=p_f$ because seismic value do not give more new information from the global proportion. (Deutch et all. 2014)

4.3 Markov-Bayes Soft Indicator Kriging

With enough data the covariance and cross-covariance function can be directly calculated. Three covariance need. The first one is the covariance between hard facies indicator data for each individual facies type, *c* from well data $C_i(h;f)$. The second one indicates the covariance among the hard indicator data and the value of the seismic probabilities from $p(f|a_i(u)$, $C_{is}(h;f)$. The last one expresses the covariance among the seismic probability values $C_s(h;f)$. The latter two covariances are given by the following model:

$$
\begin{aligned}
&C_{IS}(u;f)=B_f C_I(h;f), && \forall h \\
&C_S(u;f)=B_f^2 C_I(h;f), && \forall h>0 \\
&=|B_f|C_I(h;f), && h=0
\end{aligned}
$$

where the B_f coefficient are obtained:

$$
\begin{aligned}
&B_f=E\{P(f|ai(u))|I(u;f)=1\} \\
&-E\{P(f|ai(u))|I(u;f)=0\} \quad \in \quad [-1,+1]
\end{aligned}
$$

E {·} is the expected value. According to the term *E{P(f/ai(u)) / I (u; f)* =1} is close to 1 if the seismic data are good, that is, the seismic predicted probability of the facies being present is very high if the facies is present. If close to 0, the seismic predicted probability of facies being present is very low if the facies not present. The *F* parameters B_f, f = 1,….,*F* measure how the soft seismic probabilities distinguish the different facies. When $B_f \sim 1$ the seismic probability data are threated as hard indicator data in any other case will be ignored.

4.4 Truncated Gaussisan Simulation

The basic idea is the generation of multiple realizations of a continuous Gaussian variable and after truncate them into series of threshold to crate categorical facies realizations. The biggest advantage of the truncated Gaussian simulation is the ordering of the facies because this facies may be genetically ordered due to the depositional processes. It is useful for transition environments. ***Figure 2*** represents that most often we could see the facies 2 between facies 1 and facies 3 due to the correct ordering. The actual proportion of each facies is equal to the area under the standard normal curve.

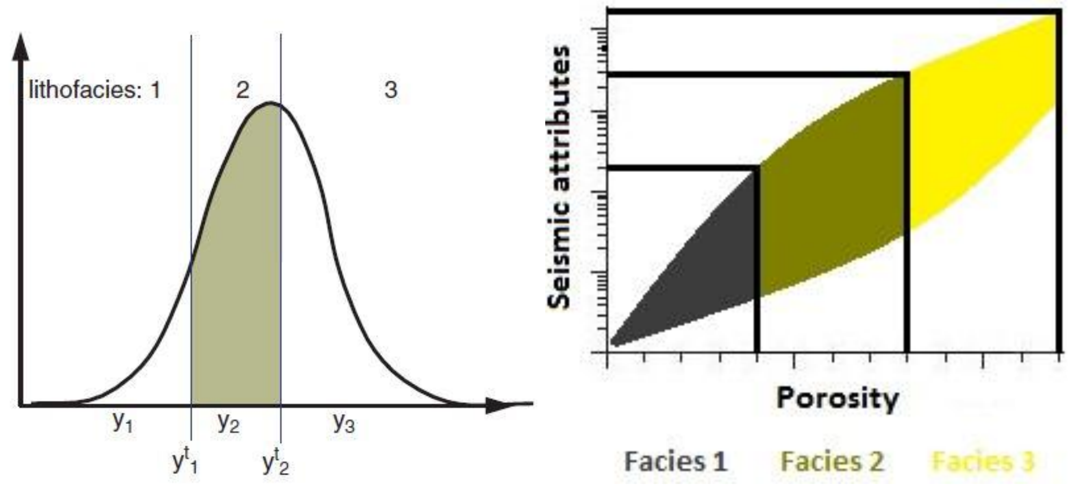

***Figure 2**: A continuous variable is truncated at a series of thresholds to create a categorical variable realization (Modified after Deutsch et all. 2014)*

The proportion of each ordered facies is known at each location u in the layer *A*, that is, *pf(u)*, *f*= 1,…..,*F u* ∈ *A*. The cumulative proportions can be described:

$$cp_f = \sum_{j=1}^{f} p_j(u), \quad f=1,\ldots,F \qquad \forall u \in A$$

Then *K-1* thresholds for transforming the continuous Gaussian variable to facies are given:

$$y_f^t(u) = G^{-1}(cp_f(u)), \qquad f=1,\ldots,F-1 \qquad \forall u \in A$$

where $y^t_f(u)$, *f*=1,…..,*F*-1, ∀u ∈ *A* are the thresholds for the truncated Gaussian simulation, $y^0_t = -\infty$, $y^t_F = +\infty$, G^{-1} is the inverse cumulative distributions function for the standard normal distribution. and $cp_f(u)$, $f = 1,\ldots,F-1$ are the cumulative probabilities for location *u*. These thresholds used to assign a facies code:

$$facies \ at \ u = k \qquad if \qquad y^t_{f-1}(u) < y(u) \leq y^t_f(u)$$

The categorical facies data must be transformed into continuous Gaussian conditioning data for conditional simulation of the stationary Gaussian variable, *Y*.

$$y(u) = G^{-1}\left(\frac{cp_{f-1}(u) + cp_f(u)}{2}\right)$$

where *y* (*u*) is the normal score transform at location u, f is the facies code at location u, and cp_f are the cumulative proportions. (Deutsch et all 2014)

5. MODEL THE POROSITY DISTRIBUTION WITHIN EACH FACIES WITH COKRIGING

The main assumption is that the porosity value *z*(*u*) can be estimated from the combination of porosity samples and the related seismic attribute samples. The estimator in terms of integrating secondary variable can be written as:

$$Y^*_{COK}(u) = \sum_{a_1=1}^{n_1} \lambda a_1 Z(u_{a_1}) + \sum_{a_2=1}^{n_2} \lambda_{a_2} Y(u'_{a_2})$$

where the λ_{a1} are the weights applied to the n_1 *Z* samples and λ'_{a2} are the weights applied to the n_2 *Y* samples. The variables need to be standardized that is the means of *Z* and *Y* are zero. The cross plot of *Z* and *Y* values provide the first assessment of the correlation between the two variables. For capturing the cross-spatial relationship between collocated values separated by *h* lag distance cross-variogram can be considered to measure this cross spatial dependence between two variables. There are possibility to avoid the cross variograms which are often hard to build. (Goovaerts, 1997) The cross-spatial relationship can be expressed by the correlation of the collocated values and the model of coregionalization also be fitted. The cross semivariogram for two variables:

$$\Upsilon_{Z,Y}(h) = \frac{1}{2} E\{(Z(u) - Z(u+h))(Y(u) - Y(u+h))\}$$

Considering standardized variables:

$$\Upsilon_{Z,Y}(h) = \frac{1}{2} E\{Z(u) \cdot Y(u) - Z(u+h) \cdot Y(u) - Z(u) \cdot Y(u+h) + Z(u+h) \cdot Y(u+h)\}$$

The covariances can be replaced by correlation coefficients with standard normal variables where the variance of *Z* and *Y* = 1:

$$\Upsilon_{Z,Y}(h) = C_{Z,Y}(0) - \frac{1}{2}[C_{Z,Y}(h) + C_{Y,Z}(h)]$$

$$= \rho_{ZY}(0) - \frac{1}{2}[\rho_{ZY}(h) + \rho_{YZ}(h)]$$

$$= \rho_{ZY}(0) - \rho_{ZY}(h)$$

The cross semivariogram at $h = 0$ is equal to 0, like the semivariogram, because ρ_{ZY} (h=0) = ρ_{ZY} (0) At the large distance when the Z and Y variables show no correlation ρ_{ZY} also approache 0. The sill of the cross semivariogram is the correlation coefficient of collocated Z and Y variables, ρ_{ZY} (0). The sill of the semivariogram is the variance, the sill of a cross semivariogram is the covariance or in the case of standardized variables the correlation coefficient at lag 0. (Deutsch et all. 2014)

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